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CVA – LEVEL I

SPECIALIST PRODUCTION PROJECT

Procedural Generation of Degraded Brick Wall Textures

Introduction

I) Background research and observation

II) Artifact generation

III) Reflection

Conclusion

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ABSTRACT

The overall goal of this project is to create a shader generating photo-real degraded brick walls.

INTRODUCTION

With this project, I wanted to explore procedural texturing and shading using RenderMan. I thought brick walls would be an interesting subject to focus my work on as there exist a lot of variations in colours and textures in real brick walls. Some shaders have been previously written on the generation of patterns of bricks but there appears to be none focusing on the degradation in colours and textures. My goal was therefore to observe brick walls and make a realistic shader that can generate a wide range of variations.

I) BACKGROUND RESEARCH AND OBSERVATION

I started this project by observing brick walls around me and recording as many variations as I could. I realized that there were a lot of differences in colours from one wall to another, created as the bricks deteriorate. So I started researching what types of deteriorations exist and what would cause them. Indeed it would be interesting to be able to link one type of wall to a specific location and weather conditions.

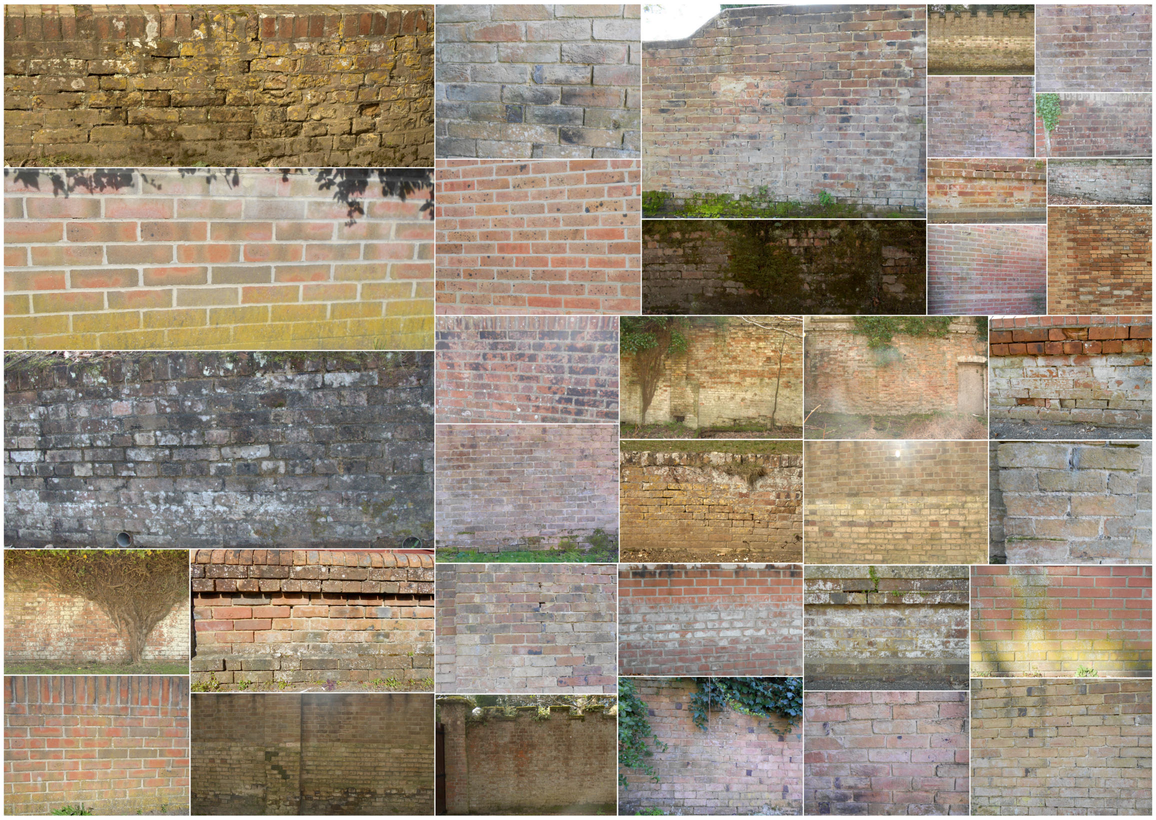


Fig 1.1 Some of the pictures I took and used as references in my project

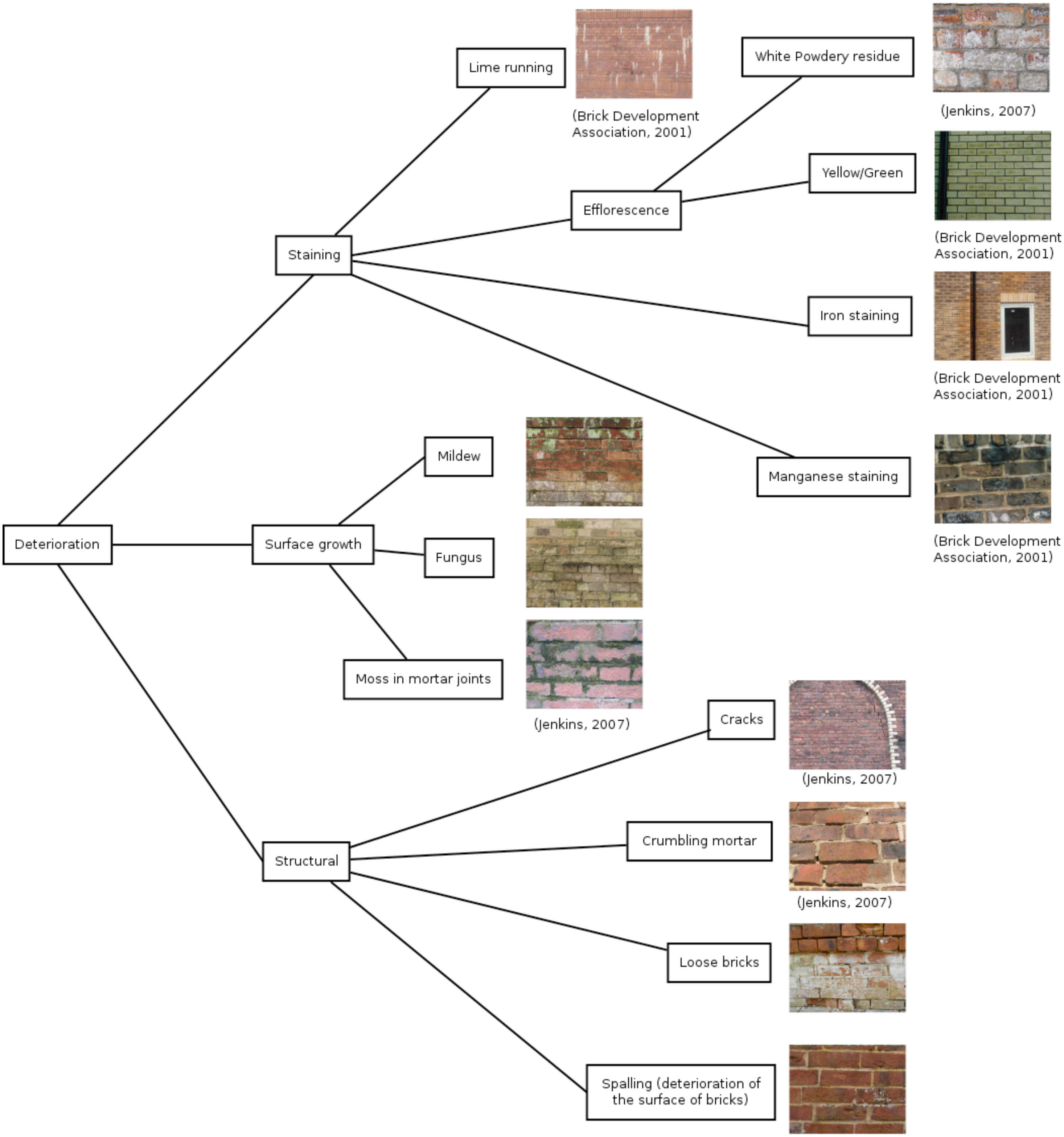


Fig 1.2 A tree of the main deteriorations of brick walls

As you can see on my summary of the main deteriorations (Fig 1.2), some of them only affect the colour of the surface (Staining), while others affect the bumpiness (Surface growth and Structural deteriorations). For more details on those degradations and their causes, see the Bibliography in the Appendix.

I looked into what work had already been done on a similar subject and found a few examples of shaders creating brick patterns. Comparing the results, I found Larry Gritz's brickbump the most successful as it contains irregularities in tiling which makes it look more man-made. I therefore decided to use it as a basis for my shader, thinking of ways in which it could be improved.

From my research, it is worth noting that more work has been done on the actual pattern generation, aiming to create realistic brick bonds. Indeed this standard "stretcher" bond is rarely used by itself. Generating patterns was not however what I was aiming at for this project so I selected a standard bond.

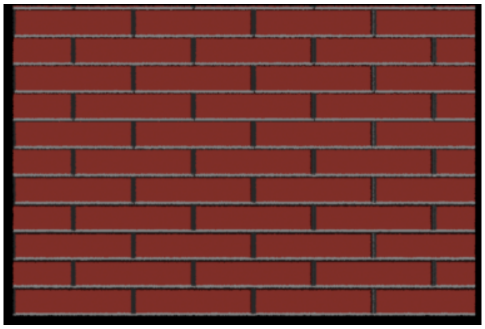


Fig 1.3 (Ebert, 2003)

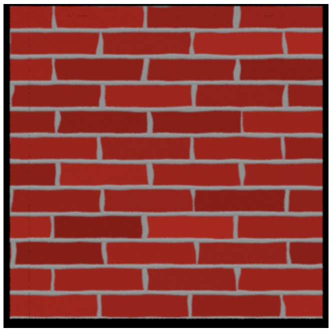


Fig 1.4 Brick shader (Gritz, 1994)

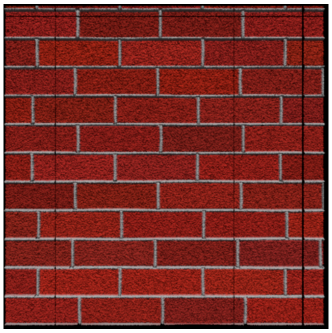


Fig 1.5 Brick and Brickbump shaders (Gritz, 1994)

II) ARTIFACT GENERATION

Following the methodology given by Cortes (2008) and May (2014), I divided my shader into main aspects, asking myself what defines a realistic brick wall – apart from the pattern:

1) each brick has a different colour as well as some subtle variations within it
2) some areas of the wall are stained in a different colour (white and yellow efflorescence, dirt…)
3) the surface of the bricks is uneven (small cracks, crumbling mortar, loose bricks)
4) there's sometimes vegetation growing on the mortar or the bricks

This essentially links back to my research and allowed me to structure my work into layers, from the most important aspect to the small details.

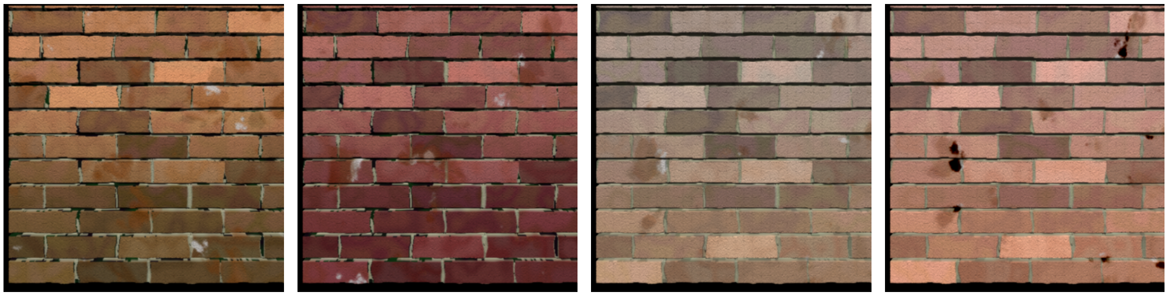
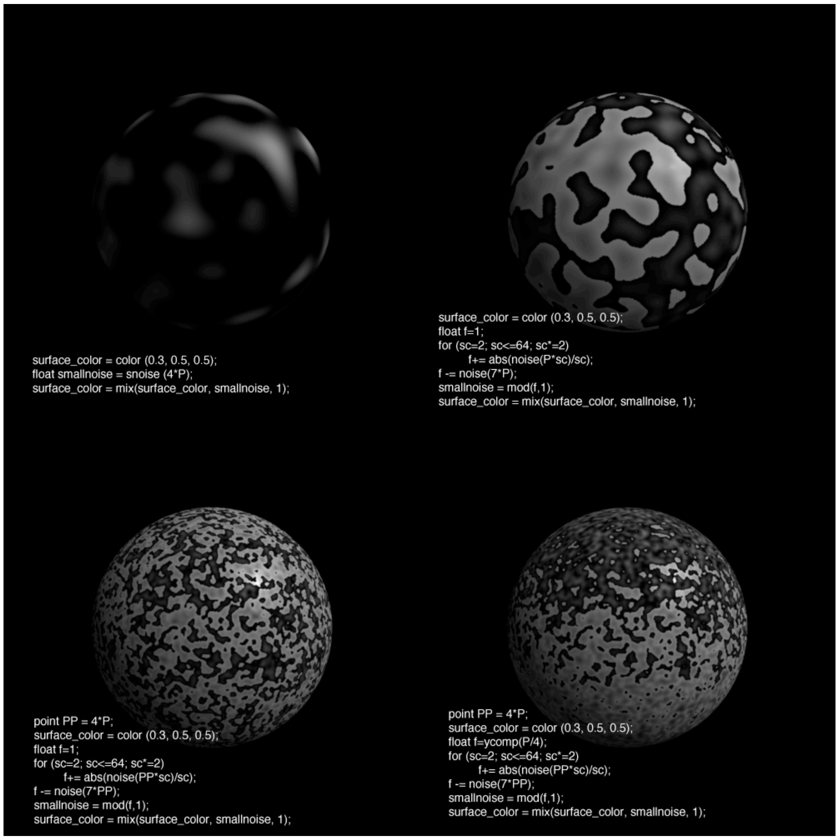


Fig 2.1 My first attempts at improving the brick wall shader

I started implementing those aspects into my work, looking at other shader codes as examples. I analyzed my results: the colours had more variations and there were some dirt and staining. But those resulting images were obviously computer generated: they lacked believability. So I asked myself what was lacking, why did the texture not appear photo real? I compared them to my reference images and realized that the level of details was not sufficient and that the way salt and dirt interacted with the surface looked far from realistic. So I started looking into each part individually, making sure I understood what each function was doing.



```
surface_color = color (0.3, 0.5, 0.5);
float smallnoise = snoise (4*P);
surface_color = mix(surface_color, smallnoise, 1);
```

```
surface_color = color (0.3, 0.5, 0.5);
float f=1;
for (sc=2; sc<=64; sc*=2)
        f+= abs(noise(P*sc)/sc);
f -= noise(7*P);
smallnoise = mod(f,1);
surface_color = mix(surface_color, smallnoise, 1);
```

```
point PP = 4*P;
surface_color = color (0.3, 0.5, 0.5);
float f=1;
for (sc=2; sc<=64; sc*=2)
        f+= abs(noise(PP*sc)/sc);
f -= noise(7*PP);
smallnoise = mod(f,1);
surface_color = mix(surface_color, smallnoise, 1);
```

```
point PP = 4*P;
surface_color = color (0.3, 0.5, 0.5);
float f=ycomp(P/4);
for (sc=2; sc<=64; sc*=2)
        f+= abs(noise(PP*sc)/sc);
f -= noise(7*PP);
smallnoise = mod(f,1);
surface_color = mix(surface_color, smallnoise, 1);
```

Fig 2.2. Tests for the salt layer

In particular, I experimented quite a lot with the noise function, in order to improve the way salt was generated. I went through the same steps for the other layers, looking at reference images to make it as close as possible to reality.

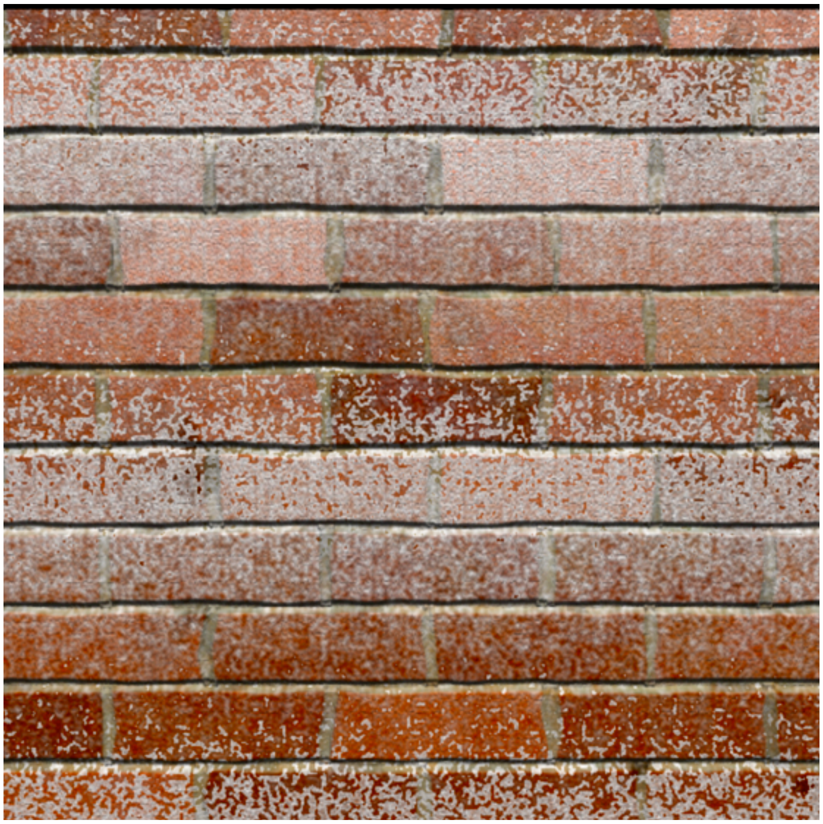
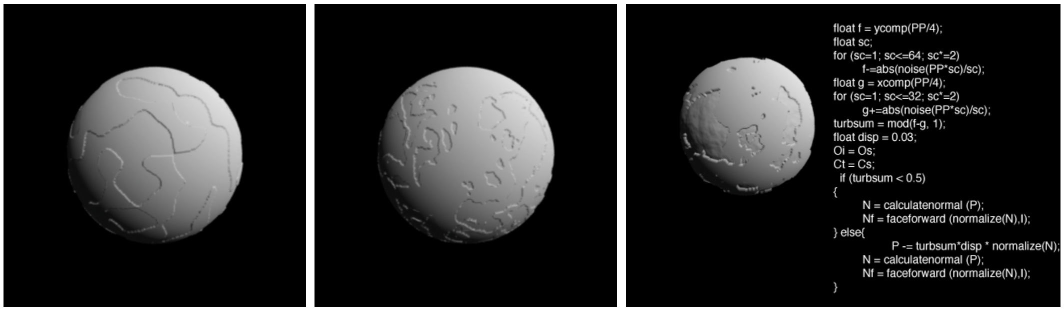


Fig 2.3 One of my results



```
float f = ycomp(PP/4);
float sc;
for (sc=1; sc<=64; sc*=2)
        f-=abs(noise(PP*sc)/sc);
float g = xcomp(PP/4);
for (sc=1; sc<=32; sc*=2)
        g+=abs(noise(PP*sc)/sc);
turbsum = mod(f-g, 1);
float disp = 0.03;
Oi = Os;
Ct = Cs;
  if (turbsum < 0.5)
{
        N = calculatenormal (P);
        Nf = faceforward (normalize(N),I);
} else{
                P -= turbsum*disp * normalize(N);
        N = calculatenormal (P);
        Nf = faceforward (normalize(N),I);
}
```

Fig 2.4 Tests for the displacement

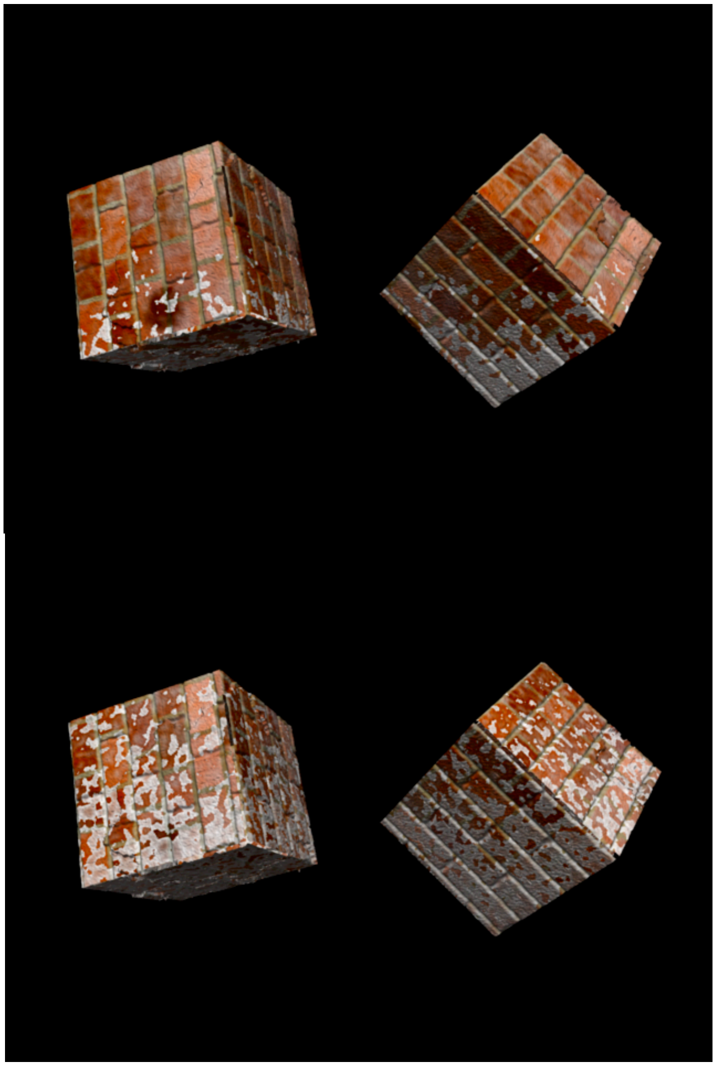


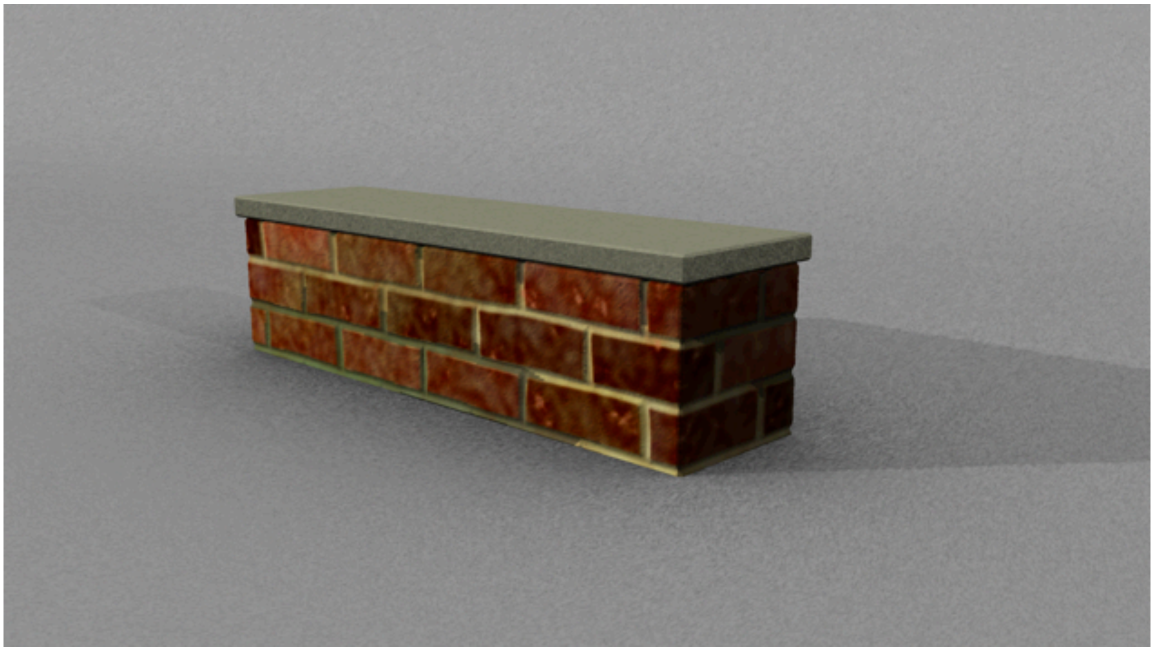
Fig 2.5 Adding cracks

III) REFLECTION

My shader can create a wide range of brick walls with different textures. However it does not create all the variations I was aiming for (the cracks or the vegetation). I started developing those but as they were quite difficult to implement, I found that I had to make a choice. I looked back at my original design and realized that they were not the most important features of a brick wall. Indeed, to recognize that it is a brick wall, those are secondary elements. So I focused on creating a variety of colours instead.

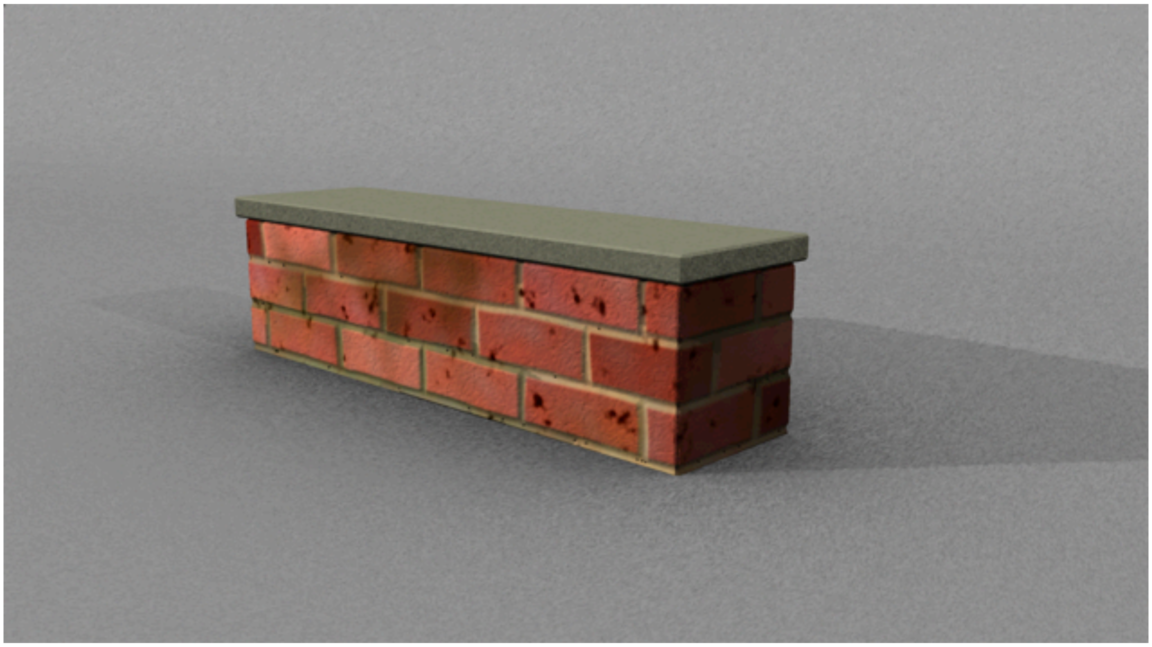
Seeing the wall in motion, we can notice that the pattern doesn’t always match up and that the displacement is not always pleasing. Creating a realistic pattern was not my goal, but if the viewer were to see the wall from that particular angle, it would instantly break the suspension of disbelief. This is therefore an issue: the shader could still be used in production to texture background walls but it would require more work if one wanted to texture an entire building. The displacement issue should also be addressed, although the issue seems to only appear for certain parameters. Further testing is required to check what works better.

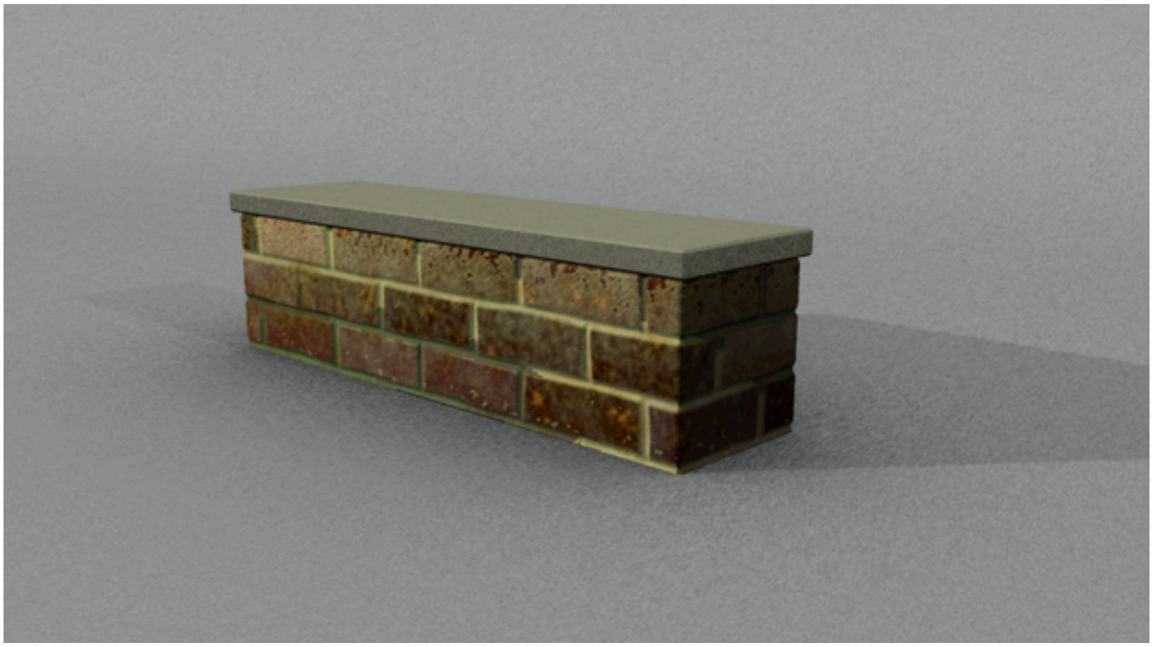
With this project, I wanted to create a photo real brick wall that would resemble the variations in colours that we can observe in degraded brick walls. My shader would still require work if it needed to be seen in a close-up or used to texture buildings. However, as a background asset, it would work efficiently. I find that I was successful in creating the colours variations I was aiming for. In terms of realism, it looks more realistic than the shader I used as a starting point, and would work in a shot given an appropriate lighting and compositing.



CONCLUSION

I managed to create a relatively photo-real shader of a degraded brick wall and it allows the user to change parameters to create different colour effects. This project helped me learn more about RenderMan and writing shaders and I feel like I can use the skills I learnt in future projects.





APPENDIX: ANNOTATED BIBLIOGRAPHY

BRICKWORK

Baker, L., 2014. Brick Work. [online] Available at: http://lauriebaker.net/images/stories/files/brickwork.pdf [Accessed 4th Apr. 2014]

This article describes different brick bonds and explains the vocabulary relevant to brickwork. As it was written by an architect, it is mainly a guide of how to achieve different patterns and how they are called. But it also contains some interesting information: we learn that nearly all bricks have the same shape and size and that their colour range from cream, through orange sandy colours to brown and even slightly blue. Those colour variations are particularly interesting to me as they imply that there exist much more variations than the usual red bricks. And as colour is one of the focuses of my project, I found this article interesting in that way.

Brick Development Association, n.d. *Bricklaying Techniques*. Technical Support. [online] Available at: http://www.brick.org.uk/wp-content/uploads/2012/04/Brick-Bonds.pdf [Accessed 4th Apr. 2014].

This documents shows the different bonds (patterns in which bricks are laid) and explain their uses. It is really clear and simple and would be an excellent reference if my work were to evolve into more pattern generation rather than focusing on deterioration and textures.

Brick Development Association, 2001. Cleaning of Clay Brickwork. *Maintenance & Repair*, [online] 41. Available at: http://www.mbhplc.co.uk/bda/Maintain-Cleaning-Brick.pdf [Accessed 4th Apr. 2014]..

This publication informs on the causes of deterioration of brickwork. We learn that excessive wetting can lead to white efflorescence but can also produce iron (orange to dark brown) and manganese staining (dark brown or black) with certain types of bricks. It details the possible staining such as lime running from mortar joints on newly built brickwork, dirt, organic growth that appears on permanently shaded and damp bricks, yellow efflorescence produced by certain salts, and calcium deposits on blue bricks. All those colours depend on the type of bricks and the weather conditions. This document is good because it analyses in depth the different causes and their visual impact but it is too detailed for my project. I need to focus first on what are the main aspects that characterize a brick wall. If the art director were to ask for something more specific then it would be interesting to dive into those different deteriorations.

Chamberlain, S. 2003. Exterior Brick Masonry Walls: Causes of and Solutions to Inevitable Deterioration. *Hoffmann Architects Journal*, [online] 21(3). Available at: http://www.hoffarch.com/assets/Journal27.pdf [Accessed 25th Apr. 2014].

This journal article intended for architects makes a list of all deteriorations and how to prevent them. There can be: staining and efflorescence, cracking, spalling, deteriorated mortar joints, loose bricks, mildew, a fungus and moss in mortar joints. It also details what causes those deteriorations, which is interesting as it depends what the bricks are exposed to (water, thermal changes) or where they are placed on a building. Those deteriorations create different colours and add a visual variety to bricks. This article provides a good description of what they are so they can each be researched further in order to implement them in the shader.

Essex County Council Historic Buildings, n.d. *Typical Details for Historic Buildings and Conservation Areas*. Conserve. Essex: Essex County Council, pp.12; 50-51.

This document aims to inform about handling different materials and how to protect them from wear and tear. It provides an interesting insight into the construction of walls. For instance we learn that walls were originally constructed using locally available materials which means the colour of brick can be affected by the location of the wall. Its colour and its bond have to match the locality. It also recommends the use of lime mortar instead of cement for historic structures. As I am interested in the deterioration of brickworks, historic structures are more relevant to my research. However, this document only alludes to the different types of mortars and brick bonds, without giving much details.

Grimmer, A. 1984. *Glossary of historic masonry deterioration problems and preservation treatments*. 1st ed.

This glossary is not only limited to bricks but it gives a lot more details on each deterioration problem than other sources. It details what the causes are and what it looks like and provides pictures for each problem. But as it treats of other materials as well, it is still too general to apply to my work.

Haseltine, B. 2014. Bricks and Brickwork. In: D. Doran and B. Cather, ed., *Construction Materials Reference Book*, 2nd ed. London: Routledge, pp.125-134.

This chapter details the different types of bricks that exist and how they evolved through history. We learn that bricks were already made in 1300 BC. from clay dried in the sun and molded into shape by hand. And over the centuries they were traditionally made locally and not transported very far. So their characteristics widely depended on the material available on the building site. This process evolved in the recent centuries and brick can now be made from sand and lime or using concrete. The history of how bricks evolved is interesting because it affects how they look at a certain time, and that is something I could add to my project: the ability to create a brick related to a certain era and time.

We also learn that mortars can have different colors to match or contrast with bricks and that efflorescence occurs often in exposed parapet walls, compared to houses walls that are more taken care of. So the texture can also depend on what function the bricks serve.

Jenkins, M. 2007. *Repairing brickwork*. Information for historic building owners. [report] Edinburgh: Technical Conservation, Research and Education Group.

This guide, aimed to inform historic building owners on brickwork repairs details the main deterioration associated to brickwork. It shows pictures to illustrate each effect, which was quite useful for my work. As far as colour variations go, it focuses on efflorescence (white powdery residue), surface growth and staining and then informs about structural faults like cracks or loose bricks. As it focuses on the main deteriorations without going into particular cases, it provides a good basis for the structure of my work.

Lesterwoods General Builders, n.d. *Bricklaying*. [online] Available at: http://www.lesterwoodsgeneralbuilders.co.uk/cdata/36636/docs/2054034_1.pdf [Accessed 25th April 2014]

This document explains all the types of bricks that exist and what they are used for. They have a different degree of irregularities depending on how automated the process is. It is a good source but as my aim is to make worn-out bricks, those differences would not make a major difference in comparison to the degradation state the bricks are in.

Lourenço, P., van Hees, R., Fernandes, F. and Lubelli, B. 2014. *Characterization and damage of brick masonry.* Springer, pp.109-130.

This chapter written by researchers in Civil Engineering and Architecture provides a chemical physical and mechanical characterization of old bricks. It also describes the damage mechanisms from a scientific point of view. The most important factors of degradation would be related to the environment (presence of moisture and salts, pollution, temperature changes,…), the materials used, the building's design, and the craftsmanship and maintenance of the building. The rest of the paper is slightly too scientific for my needs but the way the environment affects degradation is worth noting.

PROCEDURAL TEXTURING

Cozzi, P. and Riccio, C. 2012. *OpenGL insights*. Boca Raton, FL: CRC Press.

This chapter discusses procedural textures in GLSL, and in particular antialiasing and noise. It does not explain any techniques behind shader writing but provides a few examples including a brick shader. As it is only intended to demonstrate the possibilities of procedural texturing in OpenGL, it does not explain how the pattern was created. It was therefore too general for my research.

Ebert, D. S. 2003. *Texturing & Modeling: A Procedural Approach*. San Francisco, Calif.: Morgan Kaufmann.

This book presents a lot of techniques for procedural texturing. It assumes that its audience already has a good knowledge of procedural texturing so it needs to be used in conjunction with books on RenderMan Shading Language. I found the first chapter particularly useful as it gives a brick wall texture as an example but the rest of the book remained too advanced for my knowledge of writing shaders.

McCombs, S. 2014. *Intro to Procedural Textures*. [online] Upvector.com. Available at: http://www.upvector.com/?section=Tutorials &subsection =Intro%20to%20Procedural%20Textures [Accessed 4 May. 2014].

On this page, a technical artist explains what procedural texturing means and what are the most used functions to compute procedural textures. He does not show any code but rather explains the technique used to get a certain result: for example he describes how to use noise to get a marble texture and talks about how a mushroom shader was written. I found those examples quite useful as

they explain functions in a practical manner rather than just theoretically. It was therefore a really good and brief introduction to procedural texturing and made me think of what kind of technique I could use in my shader.
Shea McCombs also gives a brief introduction to Shaders on another page. It explains quite clearly how shading works with the lighting vector and the normal vector and what the Lambertian shading model is. For the purpose of my researches, I did not need a complex illumination model in my shader as bricks do not have a peculiar way of reflecting light. Therefore understanding a simple plastic model was enough and this article was interesting in that way.

Neyret, F. 2014. *Texture Page*. [online] ww-evasion.imag.fr. Available at: http://www-evasion.imag.fr/~Fabrice.Neyret/textures/textures-eng.html [Accessed 4 May. 2014].

Some techniques presented on this website by a researcher, are worth looking at, such as how to synthetize bark or clouds. It helps to visualize what techniques can be used to solve a particular problem and helped me think about how I could make my shader to get the intended results.

Oliveira, G. 2011. *Procedural Texture Mapping using Geodesic Distances*. Master of Computer Science. Universidad Federal do Rio Grande do Sul.

This dissertation treats about the use of Procedural Texturing and texture mapping. It explains concepts such as how to add chaos with noise, what cellular texturing is and what solid texturing is used for. How Oliveira then applied those concepts in his work was less relevant to my project but the background research on the methods used is well explained and avoids giving complex details on each function.

Sperl, G. 2013. *Procedural Generation of Brick and Stone Textures*. Bachelor of Science. Vienna University of Technology.

In this thesis, Sperl presents a method for procedurally generating realistic brick textures, which are based on real brick bonds such as the ones I researched in the "Brickwork" part of this report. It uses Worley's cellular textures as a basis to generate a variety of brick patterns that never intersect with windows or other walls, similarly to what we find in reality. Again, this pattern research is a useful supplementary information to my project and could be represent the step forward in my work.

Wonka, P., Watson, B., Muller, P., Hanson, E. and Eskuri, N. 2006. *Procedural Modeling of Urban Environments*. Siggraph 2006 Course 10.

This course presents the state-of-the art techniques used in procedural modeling for urban environments. It presents a method for modeling architecture using a grammar (a set of rules, derivation and then a geometric interpretation of the generated symbols) and a technique that creates more and more details iteratively. This is a good process as one can think of a texture as different states of details from the whole to the most detailed part, similarly to what Shea Mc Combs explained. It also presents how complex brick patterns generated with cellular texturing can be used to augment existing geometry. But the paper related to this technique focuses on the pattern generation of brick walls rather than textures and colours so it cannot form the basis of my research but could be interesting as a way to expand my work.

SHADING PRINCIPLES

Alexa, M., 2014. *Shading from Shape*, Conference Forward! on 3D Printing, FMX

Although this conference was about 3D printing, it focused on the interaction of light with the shape and material of an object and how surface normals affect shading. I found it really useful to understand how light reacts with materials and how bump mapping works. Indeed, as Marc Alexa was researching a way to reproduce in real life the effects we can get with bump mapping in CG, he explained those principles in depth, which later helped me apply it to my shader.

Olano, M. 2002. *Real-time shading*. 1st ed. Natick, Mass.: AK Peters.

In this book, Olano presents different shading languages and in particular he compares RenderMan with PfMan (PixelFlow). He provides an example of a brick shader for both and explains the differences in syntax and the way it handles variables. However, it does not actually draw any conclusion and although it compares the way PfMan and RenderMan work, it does not compare the resulting images. It does not tell us which one provides the best results and as the images given are quite small and in black and white, we cannot draw any conclusion ourselves. This book was therefore not really useful for the purpose of my research.

RENDERMAN

Apodaca, A. A., Gritz, L. and Barzel, R. 1999. *Advanced RenderMan*. San Francisco: Morgan Kaufmann.

In this book, shading is clearly explained, without jumping any steps. In the pattern generation part, some useful functions are listed and described and they are applied later on in a few examples, providing a good insight into writing shaders.

Cortes, R. and Raghavachary, S. 2008. *The RenderMan Shading Language Guide*. 1st ed. Boston, MA: Thomson Course Technology.

This book is exclusively about writing shaders in RenderMan. It walks the reader step by step into writing a watermelon shader, explaining how each decision is made which makes the process really easy to understand. It would have been good to have more examples like this one as I found the rest of the book less useful for my project.

Gritz, L. and Apodaca, T. 1999. *Advanced RenderMan: Beyond the Companion*. Siggraph 1999 Course 25.

In the “Writing Surface Shaders” part of this course, Tom Porter presents a methodology for writing shaders. He illustrates the “divide and conquer” technique by explaining how he would approach writing a mango shader. I find this paper really useful to understand how to approach shading and what every line means. It gave me a technique to apply to my own shader.

Lancaster, T. 2014. *RenderMan® Repository*. [online] Renderman.org. Available at: http://www.renderman.org/RMR/ [Accessed 25 Apr. 2014].

This website contains a lot of shader codes, which proved really important in my project. It has a few brick shaders that I could compare to see what worked better for my project. Instead of starting with blank shader, I could therefore use some of the code present on this website and study it to understand how it worked. Other shader codes, not specifically related to bricks, were extremely useful as well to understand how to implement a range of techniques, in order to get specific results.

Macey, J. 2014. *Introduction to Renderman*. [online] NCCA. Available at: http://nccastaff.bournemouth. ac.uk /jmacey/BA2Renderman/index.html [Accessed 20 Apr. 2014].

Those course notes are a good introduction to RenderMan and writing shaders. They do not deal with my problem in particular but help to understand the basis

of RenderMan Shading Language.

Malcolm, K. 2014. *CG References & Tutorials*. [online] Fundza.com. Available at: http://www.fundza.com [Accessed 25 Apr. 2014].

This website contains a lot of useful tutorials about RenderMan. It explains how to use certain functions, giving examples every time. It is a helpful reference as sometimes short explanations like the ones found in the RenderMan Companion are not enough to describe what a function does.

May, S. 2014. *RManNotes*. [online] Accad.osu.edu. Available at: http://accad.osu.edu/%7Esmay/RManNotes/ [Accessed 22 Apr. 2014].

This website presents a methodology to write shaders in RenderMan, using a layered approach and a specific naming convention. It does not have a lot of pages but the information they contain is really useful and well explained. It helped me structure my shader and understand where to start from, as it explains the method presented in Siggraph 1999 Course 25 a bit further.

Pixar Animation Studios, 2014. *The RenderMan Interface*. [online] Webstaff.itn.liu.se. Available at: http://webstaff.itn.liu.se/~stegu/TNM022-2005/Pixar_RPS_12.5_docs/prman_technical_rendering/users_guide/RISpec-html/ [Accessed 4 May. 2014].

I used this reference in the same way as The RenderMan Companion: it provides a list of RSL Functions and Control Structures that are useful as quick references, to make sure of what the function does and what the proper syntax is.

Renderman University, 2014. *RenderMan University*. [online] Available at: http://renderman.pixar.com/view/renderman-university [Accessed 20 Apr. 2014].

Pixar's website has a lot of information about RenderMan: from the fundamentals to a list of the predefined variables or to in-production examples of shading. I found this latter category particularly useful as it shows the design process of a

shader, for instance for a coral reef. It explains how they approached shading and what researches they undertook, which informs on writing shaders in general.

Stephenson, I. 2007. *Essential RenderMan*. London: Springer.

For this project, I was mainly interested in shading and procedural texturing. But I still needed to understand the basics of RenderMan before being able to write shaders. I found this book was a really clear introduction and the different possibilities that it gives us. The part on repeating patterns was also quite useful and the code well explained, as it is not expecting its reader to have a prior knowledge of RenderMan and writing shaders.

TD Channel, 2012. Introduction to RenderMan Shading Language (RSL) [video online]. Available from: https://www.youtube.com/watch?v=yfXCswFIkFY&list=PLBC9BDF8977F9F567 [Accessed 20th April 2014]

Those videos are a good introduction to RSL and Procedural Texturing, as they do not expect the viewer to have any prior knowledge in the area. They explain the idea of layering and how simple functions like smoothstep work and going step by step to write a simple shader.

Upstill, S. 1990. *The RenderMan companion*. 1st ed. Reading, Mass.: Addison-Wesley.

This book is a bit outdated so it does not offer a simple introduction to RenderMan. However, used in conjunction with other books, it is a really good resource as it lists all the functions used in RSL, providing the type of parameters used and a short explanation of the function. Some of its example shaders are also quite helpful as they demonstrate a wide variety of possibilities in shading.